



SUSTAINABILITY IN AGGREGATES PRODUCTION IN FINLAND

Exploring Sustainability Practices in the Finnish Aggregates
Industry

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Abstract

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This thesis aims to find out if there is a financial benefit from being a sustainability forerunner and what kind of an impact the regulation and new technology have on the operations. Crushed rock is an important part of construction operations and is the biggest component in concrete and asphalt, but as it is not a renewable material, it makes the whole aggregate industry initially unsustainable.

International studies also show that there are several other harmful impacts on the environment, like CO₂ emissions and reduction of the forest areas, from the quarrying operations, and the noise and dust cause health issues for the workers. The connection between sustainability initiatives and financial success has not been studied specifically in the aggregate industry, but in other industries, positive results could be found. This thesis studied the insights and experiences of Finnish aggregate producers regarding their stance on sustainability, thoughts about legislation and regulation, experiences of issues with equipment, occupational safety, and whether sustainability initiatives bring financial benefits.

The study was conducted with semi-structural interviews to find out the insights and experiences of the aggregate producers. This approach allows the interviewee to freely tell their thoughts in a broader scope, and for the interviewer to ask additional questions to deepen the conversation.

The results show a positive relation with sustainability within the research group. The legislation is experienced to be strict and interpretations differing between areas, and the regulation is expected to become stricter in the future. The interviewees shared their experiences with the problems caused by unreliable newer technology. Sustainability efforts were seen as a cost issue mainly, but some indicated the positive effect on company image and for some as a possibility to bid for a larger scope of tenders.

This thesis was commissioned by Metso Corporation.

Keywords Sustainability, aggregates, comminution, safety, ecology

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Contents

1	Introduction	1
1.1	Background of the study	1
1.2	Main research question and objectives of the study	4
1.2.1	Main research question	4
1.2.2	Objectives of the study	4
1.3	Metso Corporation.....	4
2	Theoretical Framework.....	6
2.1	The operating environment in aggregate production	6
2.1.1	Environmental impacts of aggregate production	7
2.1.2	Preventative measures in the operation	10
2.2	Mobile crushing units	12
2.3	Domestic regulations	15
2.4	Regulation from the European Union	16
2.5	Sustainable Development Goals	16
2.6	The Paris Agreement.....	17
2.6.1	The European Union’s climate neutrality	18
2.7	Metso’s sustainability program	18
2.7.1	Planet Positive.....	19
2.8	Economic success and sustainability	21
3	Research design.....	23
3.1	Research philosophy	23
3.2	Research methodology	25
3.3	Data collection.....	25
3.3.1	Semi-structured interview.....	26
3.3.2	Interview execution and research group.....	27
4	Findings and discussion	29
4.1	General thoughts about sustainability	29
4.2	Current regulations and requirements	30
4.3	Changes in the regulation and requirements	32
4.4	Regulation trends	34
4.5	Issues with regulations.....	35

4.6	Issues with safety and environmental features in equipment	36
4.7	Changes made to equipment properties	38
4.8	Accidents with equipment	40
4.9	Benefits for sustainability forerunners	41
4.10	Discussion	42
5	Conclusion, limitations, and future research	45
5.1	Conclusion.....	45
5.2	Limitations of the study	46
5.3	Future research.....	47
	References	48

Figures and tables

Figure 1.	Description of Metso's offering range	5
Figure 2.	A cartoon-style portrayal of aggregate production	7
Figure 3.	Typical two-stage crushing station	9
Figure 4.	Heavy dust cloud arising.....	11
Figure 5.	Lokotrack Urban -series crusher.....	12
Figure 6.	Mobile jaw crusher	13
Figure 7.	Mobile cone crusher with a pre-screen.....	14
Figure 8.	Mobile cone crusher with a product screen	15
Figure 9.	The SDGs Metso refers to (Metso Corporation.....	17
Figure 10.	Metso's sustainability handprint and footprint	19
Figure 11.	An external power connection for a mobile screen	20

Figure 12. The research onion	23
Figure 13. Research design	26
Figure 14. A typical gravel pit	31
Figure 15. The finger safety guards	38
Figure 16. Service platforms of a mobile unit	40
Table 1. Overview of data collection.	28
Table 2. Simplified stances for different topics.	43

Appendices

Appendix 1. Topics of the interviews

Appendix 2. Data management plan

1 Introduction

1.1 Background of the study

Finland is very dependent on the construction industry. From the gross domestic product, the share of construction investments was 15% in 2022, which is above the average of the Euro area (11,6%). At the time of writing this thesis, the construction industry is dramatically decreasing. The volume of apartment construction decreases by about 40% and will continue falling in 2024. The main reasons behind this are the high interest and cost level and tightening financing. The apartment construction is expected to make a turn in 2025. The road and railroad construction are also decreasing, but the Finnish government has an investment program of three billion euros for the infrastructure. Building of business premises is still on a positive trend and is likely to remain so in 2024, as well. (Rakennusteollisuus RT ry, 2023)

Aggregate production means making different size ranges of rock materials for different, usually for construction or raw material, purposes. Materials extracted from natural resources, like bedrock, gravel ridges, or seafloor, are called primary aggregates. Secondary aggregates are made from recycled materials, like excess concrete from factories, bricks and concrete from demolition sites, and by-products like slag from other industrial processes. (Aggregates Europe – UEPG, n.d.-a)

The applications for aggregates are comprehensive. About half of the produced aggregates in Finland goes to road construction and 10% is used for asphalt production (Geological Survey of Finland, GTK, 2019). Roads have several layers of different material sizes as a base, and asphalt as the surface layer, for example, of which 95% is aggregates (Sorri, n.d.). Railways have the base layers and railroad ballast visible on the tracks, yards have crushed rock as the surface layer and ballast next to and inside the foundation of houses, playgrounds have their terrain often from gravel, and in wintertime, aggregates are used to prevent slipping on roads and sidewalks (Huhtinen et al., 2018, p. 23). One of the most important applications for aggregates is concrete production as from the volume of concrete, aggregates are 65-80% (Suomen Betoniyhdistys ry, n.d.). In Finland, the share of total aggregate usage for concrete products is about 10% (Geological Survey of Finland, GTK, 2019), but in Europe, it is about 45% (Aggregates Europe – UEPG, n.d.-b).

Rock is not renewable, so as a resource, it is not sustainable - but as it is currently irreplaceable, the production should be sustainable. The standards are now made from a technical point of view, but the sustainability aspects might be in the spotlight in the future. The sustainability aspect is not only limited to the crushing site, as the need for the aggregates might be a long distance away, which leads to emissions, dust, and noise from the transportation, even if the activity on the production site would be sustainable. (Danielsen & Kuznetsova, 2016) As primary aggregates are not sustainable, the best sustainability act would be to use it less. At the same time, construction and demolition waste is a big and growing problem in the world. The European Union has set a target for the member countries to recover and recycle 70% of the generated non-hazardous construction and demolition waste by 2020. A lot of the EU countries reached the target or were quite close, but Finland, for example, was one of the worst with a recovery rate of only 12%. There are a lot of studies on the use of recycled construction waste materials to produce new concrete and ceramic materials, asphalt, and to use them in sea-wall foundations and landfill top layers, for example. (dos Reis et al., 2021) As concrete is so high in aggregate content, there are studies for replacing it with recycled materials, such as crushed car windshields (Arabi et al., 2019), copper slag, coal bottom ash, and foundry sand (Srivastava & Singh, 2020).

Finland is one of the biggest aggregate producers per capita in Europe (European Aggregates Association, n.d.). In the past few years, the demands for the sustainability of production have gotten tighter through EU regulation (European Union, 2019) and, for example, Finnish cities' pursuit of cleaner production and reduced emissions (Sitoumus2050, n.d.). To provide desirable and functional solutions for their customers, equipment manufacturers need to get feedback from the customer interface, as otherwise there is a risk of designing products that seem to work well on the design table but will never be accepted by the operators.

Some Finnish aggregate producers have their own corporate sustainability programs and targets. Rudus Oy, a part of the international CRH Corporation, produces aggregates and concrete in Finland. Their sustainability program includes the target of zero accidents, retaining biodiversity, and carbon neutrality in all its operations by 2050. (Rudus Oy, n.d.) Swerock Oy is a very similar operator. It is a part of Peab Corporation, which is listed in the Stockholm stock exchange, and is focused on aggregates and concrete production. They also have sustainability initiatives and have developed an environmentally friendlier concrete product, which has up to 50% less carbon emissions. (Swerock Oy, n.d.) NCC owns extraction areas but usually, they have a contractor operating the production and transportation. They have invested in biodiversity for over ten years and have several

projects where the quarries have been restored to their natural state and in co-operation with environmental organizations, the areas have been made into wetlands, meadows, and xerothermic habitats, for example. (NCC Corporation, n.d.) Destia Oy, a part of the Colas Group, is a similar operator as NCC, using contractors for aggregate production. They have set a target of being carbon neutral by 2030 and climate positive by 2035. They also aim to reduce third-party indirect emissions by 30% by 2030, compared to the level of 2020. These emissions come from the asphalt and concrete production, for example. (Destia Oy, n.d.)

One part of making construction more sustainable is the use of waste materials. From a bedrock area in Espoo, granite is being extracted and parts of the quarry are filled with wasteland from construction sites at the same time. After the quarry is shut down, it will be filled with wasteland. Despite the name, the material is soil, clay, and sand, which has not found any use in other places. These places can be a very fertile ground for biodiverse nature, like in Vuosaari, Helsinki. Helsinki reuses 80% of the wasteland generated from construction sites. This procedure reduces emissions from transportation when these materials do not have to be carried further away to landfill sites. (Moilanen, 2020) Planning is the key to reducing the amount of generated wasteland. Identifying the materials from the site that can be reused and what needs to be carried to a landfill site. The maximal reuse of materials is a key factor in reducing the required amount of primary aggregates. (Laurila, 2020)

This thesis examines the views of Finnish companies producing building materials on sustainability. It focuses on their perspectives regarding environmental aspects, safety measures, and potential economic benefits. The study also looks at their practical experiences with modern technology in their plants and examines how regulatory requirements and market demands have influenced their practices. This work starts with introducing the subject and the commissioning company, the theoretical framework in the second chapter including a presentation of the industry and regulation both in Finland and in the EU, and then introducing studies related to sustainability and financial success. The third chapter is about the design of the research and the results and analysis comprise the fourth chapter. The fifth chapter includes the conclusion, compiling the results of this work, presents the limitations of this study, and points out possibilities for future research.

1.2 Main research question and objectives of the study

1.2.1 Main research question

The experiences of Finnish aggregate producers about sustainability or regulations regarding it have not yet been studied earlier, and similar international studies were not available either, in this specific business area. The main research question of this thesis is to find out to what extent sustainability initiatives in the aggregate production industry impact the producers' financial performance, and how current regulations and technologies influence the industry's operations and financial outcomes.

1.2.2 Objectives of the study

To find out the answer to the main research question, two objectives have been set for this study:

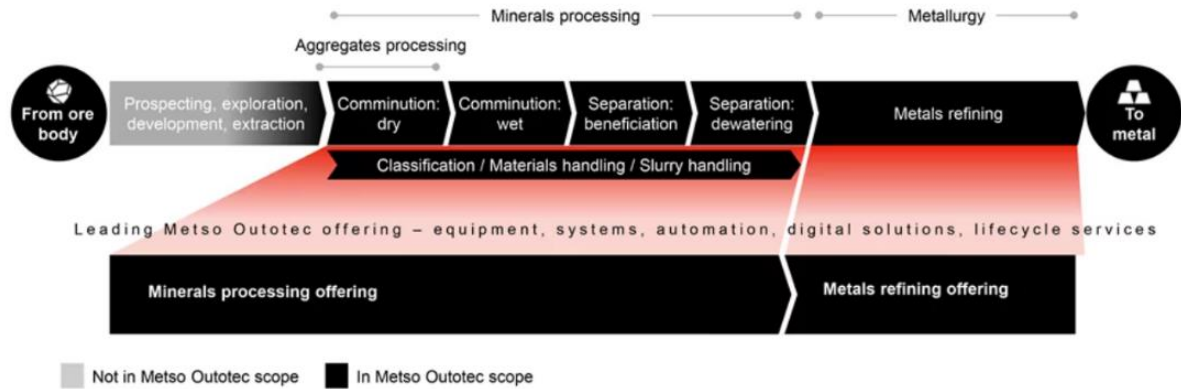
- To assess the financial impact of sustainability initiatives in the aggregate production industry.
- To analyse the influence of existing regulations and technologies on industry operations and sustainability outcomes.

1.3 Metso Corporation

Metso Corporation (later Metso) is the commissioner for this thesis. Metso is a leading company with offerings in the aggregates and minerals market, and in sustainability and technology. Annual sales are 5,3 billion euros (2022) and Metso operates in over 45 countries, with over 16 000 employees. Planet Positive sales were 1,3 billion euros in 2022. (Metso Corporation, 2023, p. 5)

Metso offers products, services, and technologies for aggregates, minerals processing, and metal refining customers with a high focus on sustainability. Metso can be a partner throughout the whole material processing starting after the extraction or quarrying (figure 1). With this comprehensive partnership, Metso can help companies to operate in ecologically friendlier ways and be more efficient regarding the scarcity of natural resources with e.g., water efficiency and recycling materials. (Metso Corporation, n.d.-a)

Figure 1. Description of Metso's offering range (Metso Corporation, n.d.-a).



Briefly described, Metso offers the equipment to crush rock or other materials, separate them to desired fractions, convey them to the preferred location, and if needed separate metals from the material and process them. With these, there are services to help the customer build up and start the production plant, and then monitor and operate the production, with other life cycle services included. (Metso Corporation, n.d.-b)

2 Theoretical Framework

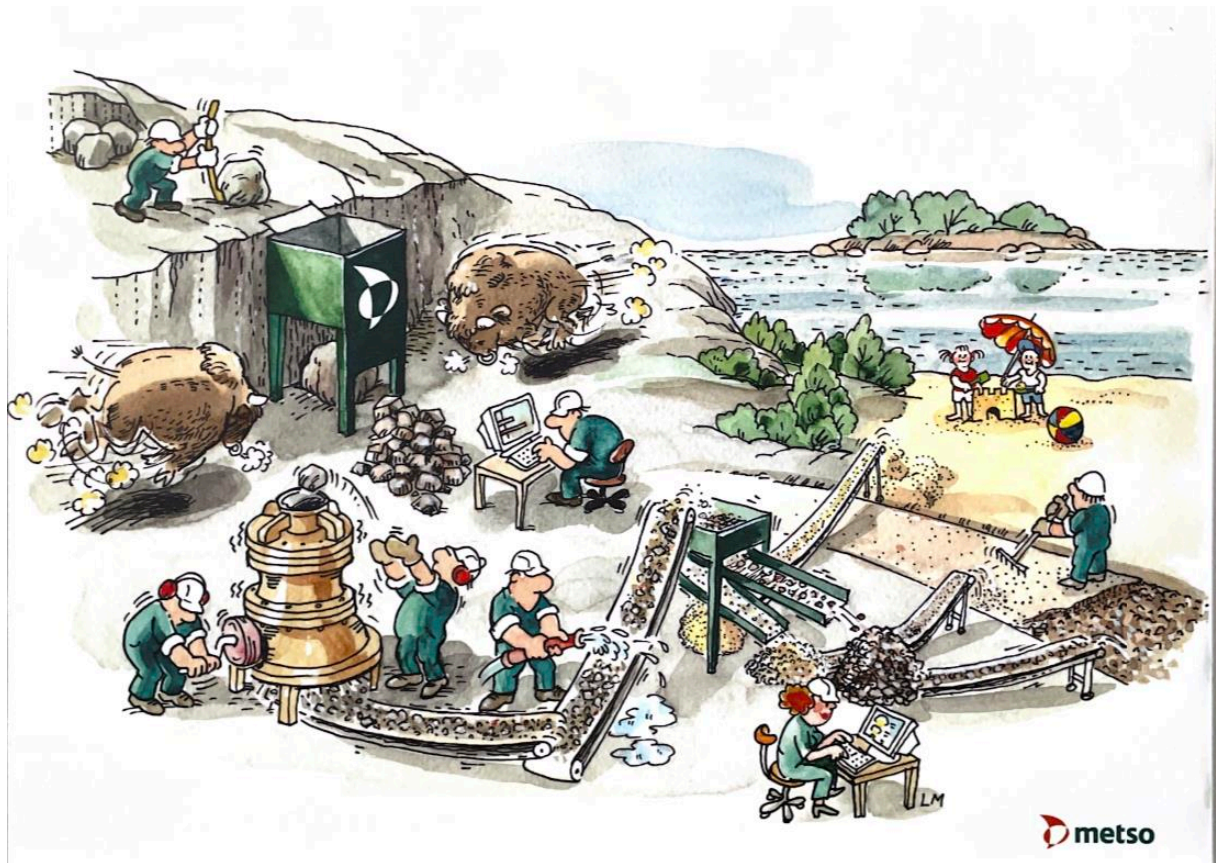
The theoretical framework comprises the current relevant regulations in both Finland and the European Union. They set the boundaries for the operation in different places; setting up the sites, operating times of year and daily hours, noise and emission (dust and exhaust gases) limits, and requirements for the equipment which can be used. The theory part also showcases results from studies of the connection between financial success and environmental consciousness.

2.1 The operating environment in aggregate production

Aggregates in Finland are usually done with mobile equipment and in two or three crushing phases. There might be an additional mobile screen as the fourth machine or possibly a vertical shaft impactor if the material needs a better shape. (Sorri, n.d.) Depending on the plan for the extraction site, there can also be a stationary station built, which will operate there for several years, whereas the mobile station travels from one site to another making usually smaller batches closer to the e.g., construction site. (Laurila & Hakala, 2010, p. 19)

The aggregate production process (figure 2) in a quarry starts with blasting the rock wall. If the blasting is successful, most of the rocks are suitable for primary crushing, but if not, then the oversized rocks need to be broken with an impact hammer. (Laurila & Hakala, 2010, p. 16-19; Sorri, n.d.) Usually in Finland, the primary crusher is a jaw crusher (figure 6) due to the hardness of the rock. Softer rocks could be primary crushed with a horizontal shaft impact crusher.

Figure 2. A cartoon-style portrayal of aggregate production. (©Metso Corporation)



As an example of a three-stage crushing process, the jaw crusher is fed with an excavator, and it crushes the up to 500-700 mm feed material into 150-200 mm size. This material is then moved with on-board conveyors to the secondary crusher (figure 7), which reduces the material size to 50-70 mm. The tertiary crusher (figure 8) works in a closed circuit, where the oversized rocks go back to the crusher until they are small enough to go through the screening media in the onboard screen module. (Lindqvist, 2008) If there is a requirement for a lot of different products, the tertiary unit can feed e.g., 0-16 mm product to a mobile screen, which then cuts it to e.g., 0-3, 3-8, and 8-16 mm end products. In a two-stage process, the crushing units work with a higher reduction ratio to compensate for the fewer crushing phases. A typical three-phase station produces 150-400 tons per hour of different products. (Laurila & Hakala, 2010, p. 19-20; Metso Corporation, 2020)

2.1.1 Environmental impacts of aggregate production

There are several different effects, which the production of aggregates causes. The site of extraction changes the way nature looks dramatically, from a forest to an open quarry pit, for example (figure 3). The different phases of production cause noise; drilling, blasting, crushing

the rock, and sirens from trucks and work machines reversing. Dust is another hindrance, which comes from the crushing phase when the material drops to the pile, and from the roads when the trucks drive into and away from the site. (Lonka et al., 2015, p. 24-26) Sairanen et al. (2018) noted that dust emissions are one of the most difficult problems, as it has the characteristics of escaping the site with the wind with no control of its path or landing. Studies showed, though, that dust emissions have decreased from the 1990's to the 2000's.

The transportation of the materials also causes exhaust gases, as do the machines operating on the site. If there are surface water areas or groundwater is running beneath the extraction area, there is the risk of contamination. The production of aggregates also generates waste material, the crushed stone fines. This material is usable for some applications, but very often there is no use for it. (Lonka et al., 2015, p. 24-26)

A study showed the environmental impacts of quarrying in northern Morocco. Open-pit quarrying produced a lot of quarry waste, mostly topsoil, for example, which with time moved as a landslide further away from the piles in the quarry. Dust emissions reached a town two kilometres away from the site when the wind was strong enough and blowing in that direction, and subjectively the noise and ground vibrations from the site were considered disturbing. Some of these problems could be controlled with better management, but the national legislation and especially monitoring it is lacking. (Agharroud et al, 2023)

Dust-related health issues were reported in a study from Ghana, where infections caused by it were doubled according to the questionnaires. Studies showed an increase in pneumonia, cough, eye and ear infections, and respiratory tract infections. In addition, the limestone quarrying in the Lower Manya Krobo District resulted in river pollution, biodiversity losses, lowering of groundwater levels and even causing buildings to fall apart due to cracks. (Nartey et al., 2012) Similar detriments were found in a study in eastern India, on the Dwarka River. The dust from quarrying operations spread to large areas, covering grain fields, contaminating surface water areas, affecting people's ears, eyes, and respiratory organs, and degrading the air quality in general. It also changed the land use from agricultural purposes to quarries. There could be an advantage for the soil quality if the amount of rock dust would be optimal, but in these findings, the amount was too large. (Pal & Mandal, 2019)

The land use for quarrying affects sustainability negatively. This aspect was studied in Ebonyi State, Nigeria. Quarrying operations often need a large land area, which means quite often loss of farmland and forest. The sites are scattered to distant places, making the monitoring harder, and due to that, the sites are just abandoned when the extraction has

been completed. This study found out that quarrying activities took 0,1% of the area, which led to a significant loss of vegetation, animal wildlife, biodiversity, and created exposure to soil erosion. (Akanwa et al., 2017) Studies from the Dwarka River basin, India, show that the land use for quarrying has been growing from the year 2000 to 2020, mostly with the cost of forest areas. It should also be noted that the effects of landscape changes are not restricted solely to the area of human actions, but it has also effect on the environment to a certain distance from the site. (Mandal & Pal, 2022)

An extensive study of several effects was conducted in Bangladesh. It had similar results as the other mentioned studies, where the landscape was considerably changed, increasing the area of barren land, and decreasing the water body and forestation areas. Near the quarrying sites and at the sites, both the dust particle levels in the air and sound levels were above the sustainable limits, exposing the people to hearing defects and respiratory diseases. The water quality of a close by river was also tested and found out it had deteriorated due to fuel spillages from the quarrying sites and direct waste dumping. (Ahmed et al., 2020)

Figure 3. Typical two-stage crushing station (Metso Corporation, 2016).



Figure 3 presents a two-stage crushing station with a track-mounted jaw crusher as the primary crusher and a mobile cone crusher with an onboard screening unit as the second phase. An excavator is feeding the primary crusher from a blasted pile of rock. There is also another excavator between the machines, which is equipped with a hydraulic hammer to break the oversized rocks smaller, so they can be fed to the crusher.

2.1.2 Preventative measures in the operation

The change in the landscape is inevitable, but in gravel extraction sites, the pit needs to be landscaped after closing the site to minimize the corruption of nature, and in some cases, it can become a place where nature can flourish (Zitting, 2018). The noise from the operation can be reduced with newer technology equipment (figure 5) and by using stockpiles and the walls of the site as sound barriers. Dust can be suppressed with water when the temperature is not so low, that the water will freeze in the pipelines. To prevent contamination, fuel tanks, possible diesel generators – and if required – the machines that are stationary when operating, need to have a trough or a plastic sheet underneath them, to stop the leaked fuel or oil from absorbing into the soil. For reducing the amount of crushed stone fines, adjusting the crushing process can help, and more applications for the product are emerging. In general, all these side effects from aggregate production can be reduced by increasing the amount of recycled materials, like crushing and reusing concrete and asphalt. (Lonka et al., 2015, p. 25-26)

A study in Italy suggested preventative measures for dust, noise, pollution, and impact on the landscape. To lessen dust formation (figure 4), water should be sprinkled on the quarry floors and yards that are not paved or cemented. Carrying the dirt from the quarry to the public roads is a problem that could be solved by washing the truck tires. For the operating diesel engines, suitable filters were recommended. The noise was not a problem for the surrounding society, but for the workers, all self-protection gear should be used to protect from the harms of extensive noise. The vibration was also studied but showed no harmful quantities further than 50 meters away, and closer to the quarry, there were no buildings. For the effects on the landscape, there were planned to be afforested areas and farmland surrounding the quarry site and removing waste rock from the site to a landfill. As a long-term plan, the site would be restored to a natural state, by adding topsoil layers, planting suitable crops and resistant species to cover the quarry faces. (Careddu & Siotto, 2011)

Figure 4. Heavy dust cloud arising. (Author's photo)



Laurila & Hakala (2010) point out the significance of setting up the crushing station to prevent dust emissions. Increasing the material flow in the dropping point and lowering the drop height reduces the amount of dust emissions. Also, a telescopic funnel can be used to restrict the open space for the dust to escape into. The terrain shapes and rock cuts can lessen the wind forces at the site and so forth keeping the dust cloud local. Internal traffic at the site causes dusting as well, so planning the locations of stockpiles can reduce the driving distances for wheel loaders, and driving slower will have a positive effect on dust emissions. Crushing is one of the primary sources of dust emissions (Sairanen et al, 2018), so encapsulating the crushing unit is a very effective means to capture the dust inside the machine (figure 5.). Using high-pressure water sprays to create a mist cloud will effectively bind the dust. On the other hand, using water might be impossible during wintertime, and might cause problems in the production process, especially in screening, by clogging the screening media. Adding substances to the sprayed water can reduce the amount of

required water and enable it to be used in winter also, but those additives are often harmful to the environment.

Mobile crushing stations make a little bit less noise than stationary ones, due to being closer to the ground level and usually smaller in size. The primary crusher makes a low-frequency sound, which travels the furthest. Good maintenance of the units is one factor in reducing the noise levels and using rubber plates in the impact areas, for example, the feeder, suppresses the sound, along with the encapsulation, like with dust. But the far most effective means to restrict noise emissions, are sound barriers (stockpiles, topsoil piles, topographic formations) and optimal location of the crushing station. (Laurila & Hakala, 2010)

Figure 5. Lokotrack Urban -series crusher (Heikkilä, 2017).



This mobile jaw crusher in figure 5 is a Lokotrack Urban unit with a rubber lining in the feeder to reduce the noise from the fed material, encapsulated crushing element to capture the crushing noise, dust covers on the conveyor, and high-pressure water sprinklers to reduce the amount of dust emissions (Metso Corporation, n.d.-c).

2.2 Mobile crushing units

In mobile crushing stations, the primary crushing unit is usually a jaw crusher. Typically, the size varies from 40 tons to 70 tons, and sometimes the primary crusher weighs over 100 tons. Usually, the primary crusher reduces the size of the feed material to be suitable for the latter crushing phases, but some uncalibrated end products can be done by only using the jaw crusher – for example, very coarse crushed stone for road embankments. If there is a

requirement for a calibrated product, it needs to be screened with a screening unit. The shape of the product from the jaw crusher is usually quite flaky and jagged. Some of the models are currently available only as diesel-hydraulic, some only as diesel-electric, and some in both. (Metso Corporation, n.d.-d)

Figure 6. Mobile jaw crusher (Metso Corporation, n.d.-e).



The secondary crusher in Finland is a cone crusher. The cinematics in the cone crusher chamber enable a lot of rock-on-rock crushing, which gives the product a rounder shape. With a secondary crusher, it is possible to make some end products, 0-31 or 0-56 mm for road base, but to have calibrated products, they need to be screened, and therefore some secondary crushing units have a hanging screening unit on the discharge conveyor. At the moment, these units are only available as diesel-hydraulic. (Metso Corporation, n.d.-d)

Figure 7. Mobile cone crusher with a pre-screen (Metso Corporation, n.d.-f).



The tertiary crushing unit is also quite often as a secondary unit, when the process is only in two phases, as these machines have a large on-board screening unit, which make also finer end products possible to make. If they are the third phase unit, they usually produce finer fractions and from one to three end products, for example, 0-8, 8-16, and 16-32 mm, which can be used in construction sites. When these machines are in the second and last phase of production, they usually produce less and coarser products, e.g., 0-16 and 16-32 mm. There are currently two different models available in the Metso offering, where the smaller one is diesel-hydraulic and the bigger unit diesel-electric. (Metso Corporation, n.d.-d)

Figure 8. Mobile cone crusher with a product screen (Metso Corporation, n.d.-g).



2.3 Domestic regulations

The primary law to determine standards and boundaries for rock crushing and screening is the Land Extraction Act, which is also meant to promote the environmentally sustainable use of land materials. This act applies to extracting rock, gravel, soil, and sand, unless it is related to mining or, for example, construction site extraction and on-site use. This act states that the extraction of resources is subject to permission unless it is for e.g., household use, forestry of agricultural purposes and related to construction or road maintenance. (Land Extraction Act 555/1981)

The Environmental Protection Act gives guidelines regarding permit processes, how to prevent contamination of the soil and groundwater, limits for emissions, and how to clean contaminations and possible compensations for breaches, for example. This act is applied to all operations which may cause spoilage of the environment and generate waste materials. (Environmental Protection Act 527/2014)

Another important act is the Muraus-act (Valtioneuvoston asetus kivenlouhimojen, muun kivenlouhinnan ja kivenmurskaamojen ympäristönsuojelusta 800/2010), which gives the guidelines to the whole production process, including e.g., emission (dust also), noise, soil and groundwater protection, waste management and preparing for accidents.

2.4 Regulation from the European Union

A big set of guidelines and regulations came with the European Green Deal, which aims to reduce 55% of net greenhouse gases by 2030 and no net greenhouse gas emissions by 2050. This brought along the different stage categorizations for industrial diesel engines. (European Union, 2019) Following this, the Prime Minister's Office initiated Sitoumus2050 - commitment, where, for example, the cities of Helsinki, Espoo, and Turku have committed to a green deal to cut the emissions at their construction sites. The target is, that they will be fossil-free by the end of 2025, and by 2030, 50% of the equipment at the sites will be operated with electricity, biogas, or hydrogen. This commitment is to promote sustainability in public procurement. (Sitoumus2050, n.d.)

EU has set a directive controlling industrial emissions. The 3rd appendix defines the use of the best available technology. This is commonly used in the requests for quotations. It points out the means of production, which generates as little waste as possible, what emissions are produced and their effects, water consumption and energy efficiency, and preventing environmental hazards. (EPNDir 2010/75/EU teollisuuden päästöistä (yhtenäistetty ympäristön pilaantumisen ehkäiseminen ja vähentäminen) 24.11.2010)

2.5 Sustainable Development Goals

The 17 Sustainable Development Goals (SDG) are the core of the United Nations' 2030 Agenda for Sustainable Development. These goals are a target for all countries to fight against climate change and preserve the environment globally, improve their economic growth, health and education, and promote equality for all. The 2030 Agenda derives from the Earth Summit in Rio de Janeiro, Brazil, in 1992, where the Agenda 21 was set. Eight Millennium Development Goals were introduced at the Millennium Summit in 2000, and the multilateral companionship was emphasized at the World Summit on Sustainable Development, in 2002. In 2012, 20 years after the first summit in Rio de Janeiro, the United Nations member states decided to start developing the Sustainable Development Goals based on the Millennium Development Goals, and in 2015, at the UN Sustainable Development Summit, the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals were introduced. Since then, an annual SDG Progress report has been introduced by the United Nations Secretary General. (The United Nations, n.d.)

Figure 9. The SDGs Metso refers to (Metso Corporation, 2023, p. 22).



Metso is referring its sustainability progress also with the Sustainable development goals (figure 9), and there are annual targets and long-term targets. For the handprint, there are the SDGs 6, 9, and 13. The target is that the sales of Planet Positive products and services grow faster than the overall sales, and that research and development have sustainability-related targets, e.g., energy efficiency, emissions reduction, or safety. By 2030, 80% of the new products need to be Planet Positive. The footprint consists of targets related to SDG 13, which are reducing CO₂ emissions in production, logistics, and procurement from suppliers. In the long term, Metso aims to net zero emissions by 2030 in its manufacturing sites. In logistics, the long-term target is to decrease carbon emissions by 20% by 2025 compared to 2019 from CO₂ emissions. Metso is targeting that 30% of the supplier spend by the end of 2025 is with partners who have also set science-based emission targets. SDG 8 is attached to health and safety, with targets of zero harm, and Metso's people and culture, targeting annual Code of Conduct training for everyone, scoring in the top 10% in the industry in Employee Net Promoter Score and inclusion, and having the same gender split in the middle and senior management as it is in the white-collar positions at Metso. As Metso has over 12 000 suppliers in about 80 countries, it looks for continuous improvement with the responsibility of suppliers, for example, by making over 100 sustainability audits annually, and 90% of Metso's suppliers have signed the Supplier Code of Conduct. (Metso Corporation, 2023, p. 22)

2.6 The Paris Agreement

The Paris Agreement was agreed upon in 2015 at the United Nations Framework Convention on Climate Change, targeting in the long-term to keep global warming below 2 °C and aiming for limiting it to 1,5 °C with collaborative actions. The participating countries agreed to make national action plans to reduce their emissions and adjust them every five years with more ambitious objectives. The countries also agreed to report how they are advancing in their plans, both to each other and publicly. The developing countries were to be aided with financing to cut their emissions and to create solutions for the upcoming consequences of climate change. (The United Nations, n.d.-b)

2.6.1 The European Union's climate neutrality

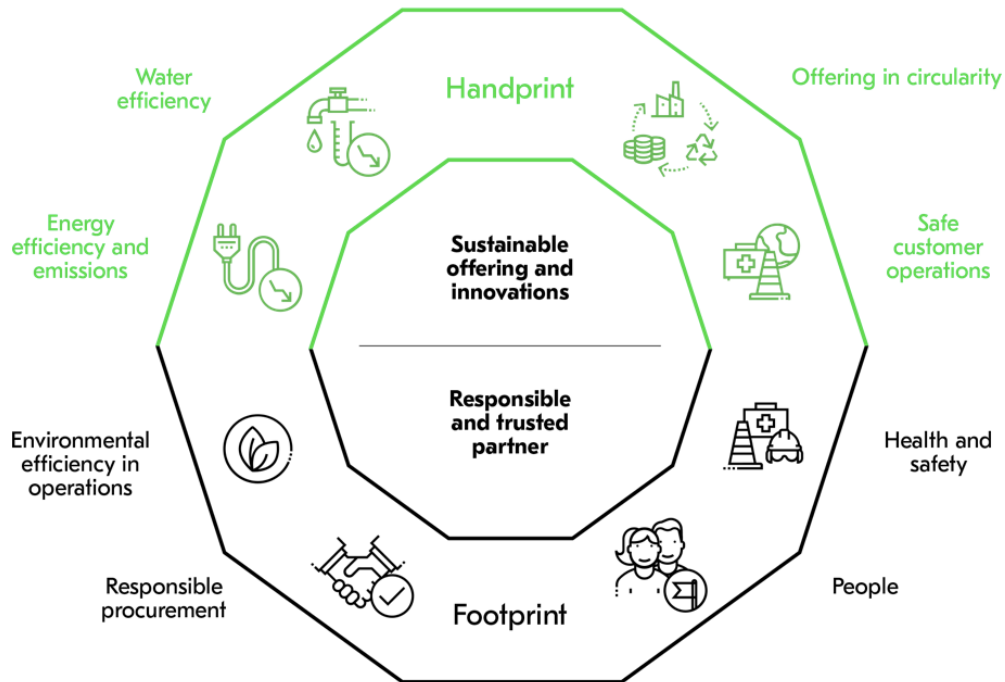
The Paris Agreement was an ignition for the European Union countries to agree on a target to reach climate neutrality in the European Union by 2050. This includes not only restraining emissions, but also increasing the absorption of the remaining emissions with, for example, reforestation and afforestation, where reforestation means establishing forests in areas where they have been, and afforestation means planting forests in new areas. (European Council, n.d.)

The European Green Deal is the main guideline for reaching climate neutrality by 2050. This deal includes investments in current environmentally friendly technologies and the innovation of new ones, developing cleaner transportation options, improving the energy efficiency of buildings, and reducing the carbon emissions in energy production – and still aiming for economic growth. (European Union, 2019)

2.7 Metso's sustainability program

Metso uses the phrase “Enable sustainable modern life” as its slogan for the company's sustainability agenda (Metso Corporation, n.d.-h). Metso has aligned its targets with the Paris Agreement to keep global warming below 1,5 degrees Celsius (The United Nations, n.d.-b). To help the world reach zero emissions by 2050, Metso aims to net zero emissions by 2030 in its manufacturing sites. This is called Metso's footprint (figure 10). Metso's handprint means their offering for customers, a variety of solutions to make their actions more sustainable.

Figure 10. Metso's sustainability handprint and footprint (Metso Corporation, n.d.-h).



This includes, for example, a screening unit with a very high G-force so washing of the material would not be required (Metso Corporation, n.d.-i), reusing and recycling mill liners (Metso Corporation, n.d.-j), a high-pressure grinding roller, HRC™, which consumes less energy than regular mills (Metso Corporation, n.d.-k), and the STOP program, which encourages personnel to decline from possibly dangerous work at customer sites (Metso Corporation, 2023, p. 31).

2.7.1 Planet Positive

Metso is committed to limiting global warming to 1,5°C according to the Paris Agreement. To reach this target, Metso launched Planet Positive in 2021, which approaches sustainability in all aspects; environmental, social, and economic. With the Planet Positive products and services, customers in aggregates, mining, and metal refining industries can reduce their emissions and improve water and energy efficiency, circularity, and safety.

Products in the Planet Positive offering need to be demonstrably better than similar products in the market regarding their environmental impact. Also, Planet Positive products must be better or at least as good as the industry benchmark products considering health and safety, pollution, and biodiversity effects. (Metso Corporation, 2022)

For energy efficiency and reducing CO₂ emissions, Metso can offer horizontal roller crushers, which consume 30% less energy than conventional mills, and with for example track-mounted crushing units, the possibility of using electric grid power instead of diesel engines will make a significant reduction in emissions (figure 11). (Metso Corporation, n.d.-k)

Figure 11. An external power connection for a mobile screen (Metso Corporation, n.d.-l).



Certain mobile crushing or screening units can be operated with an external power source. It either gives power to the on-board generator in crushing units or empowers the hydraulic unit in mobile screening units (figure 11).

Water is running short already in many places, but washing is used a lot in metals and aggregate processing. Metso can offer technologies to recover more water from tailings, where most of the water is lost, or for example, highly efficient screening equipment for moist materials, so no washing would be even required. (Metso Corporation, n.d.-i)

Extending the lifetime of equipment, making them easier to update instead of replacing, is also a way to make production more sustainable. When new technology is available, the customers can implement it to their existing equipment and reduce the amount of waste. Metso is also developing processes to recycle and reuse wear parts, and currently, a mill lining recycling service is already available. (Metso Corporation, n.d.-i & n.d.-m)

2.8 Economic success and sustainability

There are no studies about sustainability and financial performance relations in the aggregate production industry, but studies have been made for other industries. Cantele & Zardini (2018) studied Italian small and middle-size enterprises in the manufacturing industry to find out about the relationship between sustainability practices and financial performance. They found out, that there were benefits from sustainability also in these smaller companies, especially in the social and economic dimensions. These increased the commitment of the companies' own personnel and other stakeholders, but the environmental actions had quite the opposite effect. The environmental effects need to be studied more thoroughly, due to the limitations of the study.

Another study had a wide variety of companies from all over the world, including 22 companies from Finland. This study found a positive link between investments in sustainability and the company's financial performance. There was also a difference between emerging and developed countries, like Finland. It was noted that developed countries are more likely to have more and stricter regulations on sustainability issues. (Poursoleyman et al., 2022) Similar results were found from a study of about 1800 European companies. Companies with transparent environmental, social, and corporate governance strategies had a lower risk of bad reputation related to sustainability actions, which had a positive influence on their financial performance. (Agoraki et al., 2023)

A positive correlation between sustainability investments, company reputation, and higher profitability was found in a study among over 100 Swedish companies listed on the Stockholm Stock Exchange. The result was positive, especially within the companies included in the Dow Jones Sustainability Index. In general, sustainability reporting is becoming a "best practice", increasing transparency of the companies, and so forth attracting investors. Competitive advantage can be achieved with sustainability efforts, but for most following others' activities, just prevents them from falling behind and differentiating in a negative manner. (Pham et al., 2021)

A literature review about the connection between sustainability activities and financial success showed that there seems to be a beneficial nexus between them, but on the other hand, companies from higher levels of sustainability requirements do seek more benefits from moving their production and other activities to countries with lower level of regulation. But if a company wants to get the gains from sustainability actions, they need to be true and

impactful, as “greenwashing” did not seem to have any positive effect on companies’ profitability. (Rahi et al., 2023)

3 Research design

3.1 Research philosophy

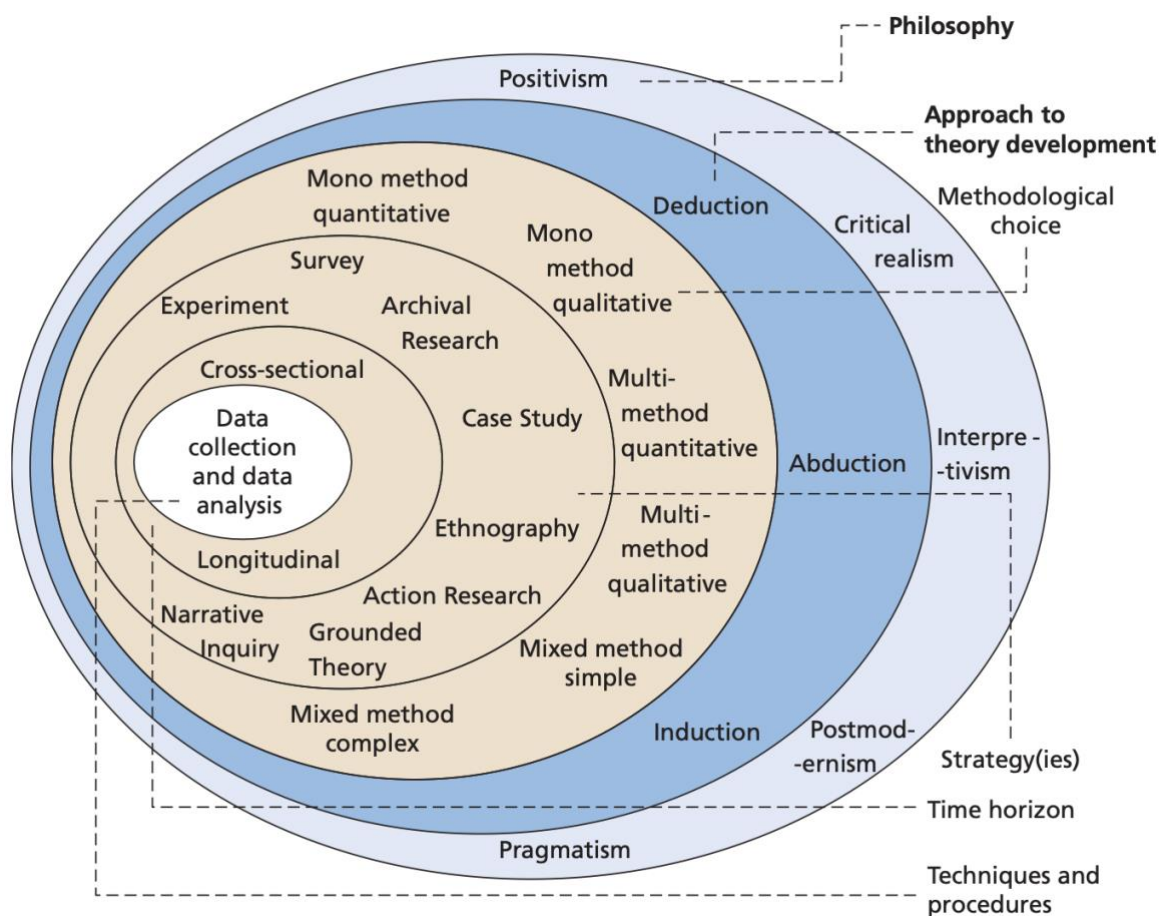
The research onion (figure 12) was applied when refining the approach to this study. The research onion was introduced by Saunders et al (2019, p. 130) and is known to be one of the most comprehensive frameworks for research. The different layers represent the choices the researchers make during their studies and demonstrate the topics that need to be considered in any research project. (Alturki, 2021)

The different philosophies for a study, positivism, critical realism, interpretivism, postmodernism, and pragmatism, provide different methods for conducting the study, depending on which stance the researcher takes. For example, studies with a positivist philosophy usually are very structured, with a large sample size, and apply a quantitative methodology, whereas interpretivism leads to small samples with in-depth investigations and qualitative methodology. Pragmatism, on the other hand, can mix both qualitative and quantitative methodologies, deductive and inductive approaches, basically whatever means are necessary to answer the research question. After the philosophy is formed, the approach will be decided. The deductive approach is often used with the positivism philosophy, providing objective, quantitative research. Deductive reasoning starts by creating hypotheses from known theories and then constructing a research to test those hypotheses. As quite the opposite, the inductive approach is often applied in interpretivism, where there is often some scarcity of literal resources and plenty of time for the research. Inductive reasoning starts with observations and theories would be applied at the end of the research, based on those observations. This gives the researcher the freedom to steer the study in different directions even after already beginning the investigation. The inductive approach applies qualitative methodologies and provides subjective studies trying to explain the meaning of subjects. Then the choice of methodology, qualitative or quantitative, and strategy for the study can be decided. (Saunders et al., 2019, p. 130-158) Qualitative studies do not see the actions of individuals originating from statistical dependencies. A qualitative study tries to understand the beliefs, experiences, perceptions, and values of people, and what are the meanings people give for their actions. The study is looking for both similarities and exceptions and due to its nature, it is not aiming to be an objective study, like quantitative studies are. A qualitative research methodology is describing numerically something in general, to what extent something has occurred or is affecting something else. The contents of the study need to be measurable and testable. Unlike qualitative studies, the quantitative methodology cuts

out the deviations and seeks general rules as to why things are like they are. (Vilka, 2021, chapter Tiedonintressi, chapters 13 & 14)

The researcher then determines the most suitable research strategy, which is dependent on the previous choices. The study also needs a time horizon, whether it is a longitudinal study or a cross-sectional one. Finally, convenient techniques and procedures are chosen. (Saunders et al., 2019, p. 130)

Figure 12. The research onion (Saunders et al., 2019, p. 130).



For this thesis, the philosophy was interpretivism with an inductive approach, which is a typical combination of small sample sizes, interviews with depth, and qualitative analysis with a range of interpretations (Saunders et al., 2019, p. 145). The methodology, strategy, time horizon, and data collection and analysis are presented in the following chapters.

3.2 Research methodology

The main research question of this thesis was to find out the influence of regulations and technologies to aggregate producers' operations, and whether sustainability initiatives have a positive or negative impact on their profitability, the research was done as a qualitative study (Vilkka, 2021, chapter Menetelmän erityispiirteet, 1st paragraph). A qualitative study as a case study aims to gather empirical information, experiences, and understanding about phenomena, where there is not much information available beforehand. (Shahzad & Arslan 2023). This study was a cross-sectional case study, where several cases were studied during a relatively short period of time, so no longitudinal elements were applicable. The selection of cases in this research gave the possibility to deepen the interviews with each participant, but also the others gave some diversity and comparison for the analysis and results. This choice of methodology was taken with the notice, that there would not be generalizability or transferability. (Saldana, 2011, p. 8-9)

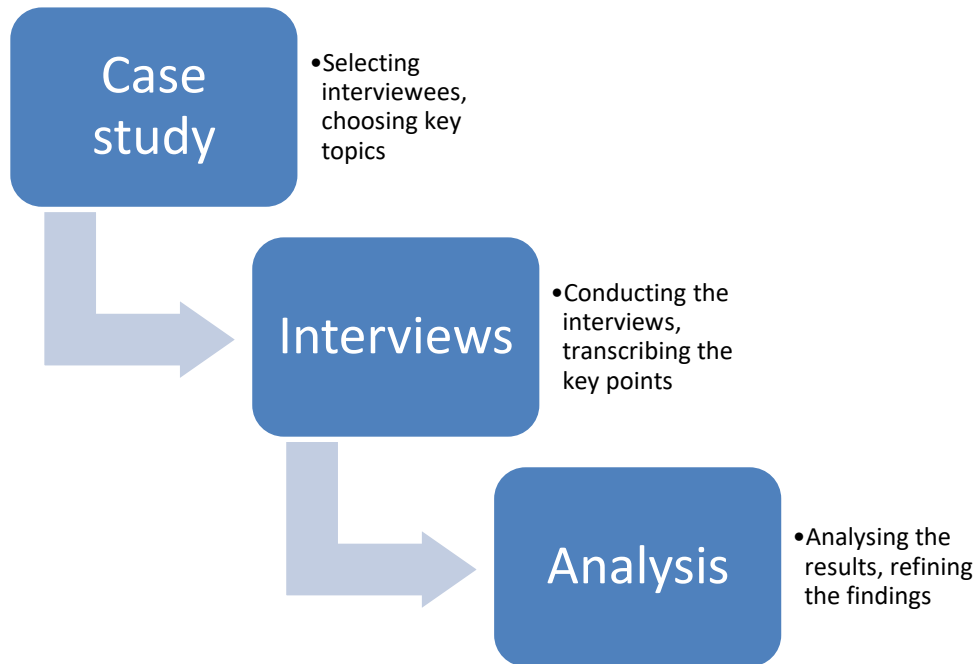
3.3 Data collection

To get the desired information, an interview would be a suitable way to engage in a freer discussion, with the possibility of asking additional, clarifying questions (Hirsjärvi & Hurme, 2022, 3.1. Haastattelun edut ja haitat, paragraph 2). The interviews were conducted as semi-structured thematic interviews, where there were a similar set of prepared questions for all interviewees, but they were not necessarily asked in the same order or with the same phrasing, but more of a discussion, which covered all of the desired topics (Hirsjärvi & Hurme, 2022, chapter Miten teemahaastattelu eroaa muista haastatteluista?, 4th paragraph).

Figure 13 shows how the procedure was planned. Before interviewing, the author went through potential operators for this study and shortlisted an encompassing sample. The topics for the interviews were derived from the main research questions. The interviews would need to enlighten how the aggregate producers see the sustainability subject in general, what are their experiences with the regulation, and do they see any financial benefits from acting more sustainable than the lowest requirements. Once the preparations were done, the interviews were scheduled and conducted. After the interviews, the key points from each discussion were transcribed for later compilation and analysis. In the analysis, the results of the interviews were broken into pieces, positioning the key points under their respective topics. Within each topic, an analysis of the stance of experience was made for each reply, whether it had a positive, neutral, or negative connotation. (Yin, 2015,

p. 184-187) This analysis was a cross-case synthesis, where the focus was on topics and addressing them comprehensively throughout all the interviews, instead of analyzing each company individually. All cases were analyzed first individually, marking up the key findings, and then comparing each case with each other to find similar patterns and resemblances. (Yin, 2003, p. 134-137)

Figure 13. Research design.



3.3.1 Semi-structured interview

The interview was meant to be like a very informal discussion, encouraging the interviewees to tell as much about their thoughts as possible, instead of having questions and precise answers. Because of that, the questions came in different orders, and the questions were not precisely the same word by word, but all topics were discussed in all interviews. (Hirsjärvi & Hurme, 2022, 4.2.3 Teemahaastattelu - puolistrukturoitu haastattelu: Miten teemahaastattelu eroaa muista haastatteluista?, paragraph 3 & 4; Saaranen-Kauppinen & Puusniekka, 2009, p. 56-57) In Finnish, this style of an interview is called a thematic interview, but there is no similar name for it in other languages. (Hirsjärvi & Hurme, 2022, 4.2.3 Teemahaastattelu - puolistrukturoitu haastattelu: Miten teemahaastattelu eroaa muista haastatteluista?, paragraph 1) Patton (1980, p. 280) called it “the general interview guide approach”. This similar type of interviewing is called usually a semi-structured interview. Adeoye-Olatunde &

Olenik (2021) describe, that this approach is a preferred data collection method, when the purpose is not to get an overview of a certain subject but to emphasize exploring the insights of the interviewees as individuals, and where the topics and questions bring more of a structure for the conversation, instead of acting as a strict guideline. The topics and questions of this thesis' interviews are in appendix 1. The deficiencies of semi-structural interviews are noted in the study made by Santo-Tomás Muro et al. (2020), where they indicate, that the process is affected by the subjectivity of the researchers, and the influences of the context of the interviews should be noted. In the end, it is up to the researched decision, how the data is collected and analyzed. It should also be considered, that the more open the discussion is, the risk of missing the most important issues for the study is higher.

According to Kallio et al. (2016), the semi-structured interview is a very common data collection method due to its ambidexterity and pliability. This method improves the mutuality in the discussion, enabling the interviewer to ask more questions related to the interviewees' replies and giving room for the interviewees to tell vastly about their opinions on the topic. This type of approach was used in a study by Shahzad and Elenurm (2020) of Finnish small and medium-sized enterprises operating in Estonia. This method was found suitable for this type of interview where in-depth discussions are preferred.

3.3.2 Interview execution and research group

The interviews were conducted during the winter and spring of 2023, nine interviews in total. The interviewees gave their consent orally after the reason for interviewing them and the procedure was explained (Hirsjärvi & Hurme, 2022, 2.3. Tutkimuksen eettisiä näkökohtia - Informointiin perustuva suostumus). When considering the desired participants, the sample would optimally include interviewees with the most information about the topics and then again participators with different points of view. The sample could also be randomized, but many of these studies do not aim for generalizable results, so purposeful selection is preferred to ensure certain criteria are met for the sample. (Adeoye-Olatunde & Olenik, 2021) The screening of potential cases for the study started from the INFRA ry. member search (INFRA ry, n.d.). Selecting "aggregates" as the main industry and "crusher" from the equipment group, the shortlist was 32 companies. From those companies, the potential interviewees were hand-picked purposefully, utilizing the author's experience and knowledge of the companies with the assistance of Metso's internal customer database, to ensure they would represent different sizes and locations, and would have mobile equipment with either diesel or diesel-electric power units, as those are more likely to have more sustainability-related topics than stations with power directly from the electric grid (table 1) (Yin, 2009, p.

91-92). All the companies work in the Finnish market and are Finnish companies, though they might have a parent company abroad. No other details of the companies are disclosed to ensure their anonymity. The interviews were finished when the point of saturation was reached, and there were no new insights received from the interviewees (Hirsjärvi & Hurme, 2022, 5.2 Kohdejoukko ja haastateltavien valinta, paragraph 9). The interviews were done at the customer's office, on-site, or in a restaurant, but ensuring that there would be enough time and no interruptions or disturbing noise to have a proper conversation (Hirsjärvi & Hurme, 2022, 5.8 Käytännön järjestelyiden suunnittelu, paragraph 7). All interviews lasted from 30 to 45 minutes.

Table 1. Overview of data collection.

<i>Case firm</i>	<i>Interviewee position</i>	<i>Number of stations</i>	<i>Electric-driven equipment</i>
Firm 1	CEO	1	Yes, only
Firm 2	Production manager	3	Yes, partially
Firm 3	CEO	2	No
Firm 4	Production manager	1	No
Firm 5	CEO	2	Yes, only
Firm 6	CEO	1	Yes, only
Firm 7	CEO	1	No
Firm 8	Production manager	3	Yes, partially
Firm 9	Production manager	8	Yes, partially

Ralph et al. (2020) conducted a similar type of a study, but their research group screening had certain conditions for eligibility to be a part of the study, and from those applicants, the participants were chosen with a purposive selection to ensure comprehensive sample, for example demographically. Purposeful sampling for semi-structured interviews was also used by Shahzad & Elenurm (2020) in their study, and as their objective was to get preferably insights instead of a large volume of data, a smaller sample size was adequate.

4 Findings and discussion

The results of the interviews are presented by dividing them into the different topics dealt with in the discussions. In each topic, there are several quotes from the interviewees, which show their exact thoughts about the issue. The answers and insights are compiled into their respective groups to highlight the division of opinions on each topic.

4.1 General thoughts about sustainability

The interviews usually started with a general discussion about sustainability, the three pillars of it (environmental, people, economic), what is interviewee's understanding of the concept as a whole, and then dividing it into smaller pieces for a more thorough view (ESG: The Report, n.d.). The overall attitude toward sustainability was highly positive. All the interviewees regarded it as the current trend and as a good thing for both the environment and the safety of employees. "You must be interested in sustainability nowadays. Consider safety aspects, act ecologically" (Interview #1). "It is the current trend and nowadays a good thing" (interview #4). "Working in a groundwater area, for example, it is necessary to keep sustainability in mind and protect the environment. And of course, personal safety is an important thing nowadays, which is a good thing, and we cherish it" (interview #5). "I think it is good for us all. There are only benefits for reducing the noise and dust from the production sites and making sure things are done properly there - and in the end, landscaping the pit look like a part of the surrounding nature" (interview #7). "Safety is one of our highest priorities and we are concerned about biodiversity, emissions and we have set targets regarding sustainability. It is a big thing for us" (interview #9).

The difference between the bigger and smaller producing companies and clients was highlighted. Bigger companies have sustainability targets for their own actions, and bigger and public clients, such as cities, municipalities, and government-owned companies have stricter regulations for their contracts, whereas small private operators and pit owners might meet just the lowest required criteria. "Very positive feelings. The producers might hold back a bit, but the customers are demanding more and more sustainability, as they have their own sustainability targets" (interview #2). "To have had the possibility to see both the bigger and smaller operators, it is obvious, that there is room for improvement in sustainability. The environmental and safety aspects are forced into action in the bigger companies, but it is a whole different world with the smaller pit owners and operators. Regarding the nature of this work, it is somewhat impossible to hit all the highest sustainability targets, but the big

companies are doing ok, but some smaller ones have not ever seen an environmental report, which should be filled.” (interview #6)

One aspect of sustainability in aggregate production is the amount of borrow pits and the transportation distances to the sites of utilization. Currently, the transportation distance for primary aggregates is rather short in general, and in big city areas, it can be about 20 kilometers (Huhtinen et al., 2018, p. 25-26). This divides the insights of the interviewees. Considering the permit processes and economic health of the companies, a lesser number of pits would be better. But for the sake of sustainability, the shorter distances cause less emissions from the trucks carrying loads. “Natural resources should be saved and increase the amount of recycling materials. Maybe higher prices for aggregates made from new natural resources and permits only for the older, bigger sites, so there would not be so many small sites all over” (interview #3). “Though the permit requirements are getting tighter, I think it is more sustainable to have the resources closer the point of use, so there would be less transportation of materials with trucks - as that has bigger downside regarding the environment” (interview #7). “Sustainability is a good thing, but common sense should be applied. The speed of the progress is too fast. The policy with permits causes now longer transportation distances for the materials, though there could be a site closer to the point of use, but one has not been granted a permit for the utilization of that site” (interview #8).

4.2 Current regulations and requirements

The current regulations and requirements can be divided into different sections: regulation regarding new and extension of permits and requirements in the tenders from both private and public clients. The discussion with the interviewees dealt with their recent experiences of applications and bids. Especially the permit policies for gravel sites are considered to be very strict at present, and in some cases, there is no possibility of getting permits. “I think it is almost impossible to get new permits for new gravel pits (figure 14) nowadays. We have not even tried for years. Water needs to be tested 800 meters away from people’s wells, even though they are connected to the public waterline, and two groundwater tests are made above and below the site. Noise tests are made with both the surface drill drilling and crushers crushing, even though they do not usually run at the same time - as first comes the drilling, then blasting, and only then the crushing. Sometimes the regulations make themselves impossible to follow. We were required to excavate a refuelling place for a wheel loader, but we did not get a permit for the excavation, because we did not have a refuelling place for the wheel loader. Because of this mix-up, the permit was delayed for one year,

before they accepted it. Bigger cities can require Stage V engines or biodiesel to be used in their contracts, but for example, the availability of the biodiesel cannot be guaranteed from the supplier” (interview #3). “There is a big difference between gravel pits with groundwater underneath and bedrock sites. The permits for gravel pits have far more precise requirements for preventing spillages and hazardous materials from going to the ground. If there are houses or cottages nearby, there usually are specific requirements for noise and dust suppression” (interview #5). “We have not had any new permits for gravel pits for the last about five years, because there is groundwater underneath them and in this area, the Center for Economic Development, Transport, and the Environment does not grant any new permits to such places. Currently, as we work only in bedrock areas, the only concerns for permits are mostly noise and dust, which we must control. I believe that our new equipment also makes things easier with the officials, even though they do not know a lot about them” (interview #6). “If there is a site close to settlement, one cannot get a new permit there. Dust and noise need to be controlled.” (interview #7)

Figure 14. A typical gravel pit (Metso Corporation, 2018).



The length of the permit process is seen as far too long, differing around the country and the knowledge of the officials is insufficient, leading to questionable restrictions and decisions. “In the environmental permit, there is a demand to use the latest available technology, but the officials do not have the knowledge to evaluate the equipment” (interview #1). “Older sites, further away from conurbation, get permits easier, if there have not been any accidents, but the closer it gets to city centres, the harder it becomes” (interview #4). “If one applies for a new permit now, it takes from five to ten years to get it. Even if someone has

absolutely nothing to do with it, one can make a complaint about it - and with no sanctions if it has no grounds. But even without any complaints, the processing time is years. The scheduling for the production is also ludicrous. In many places there is a two to three-month production break during summertime, even though that would be a time when dust could be easily suppressed with water, the production would be economically efficient and the job would be done a whole lot quicker than in winter, when it is -20 degrees Celsius outside. But the weirdest thing is, that there are big differences in different places. It is up to the officials how they interpret the rules" (interview #8). "There is no consistency with different areas in Finland regarding the permit policies. In one place it is looser, but in some places the requirements are unreachable. One example is the working time, where there can be restrictions even in places in the middle of nowhere. There can be a break set to start in June and end in October. And usually, we know the required materials in April or May, so we can not anticipate anything, and so forth we need to keep massive stockpiles" (interview #9).

The shift to demanding more environmentally friendly solutions in production has emerged and the interviewees emphasized the variation between clients of different sizes. "Recently got a first tender with a requirement of using biodiesel in all equipment, except crushers and screens" (interview #1). "Bigger customers are asking for higher emission classes for engines, using renewable energy and so on, but the smaller pit owners are more just about getting adequate quality product with as low price as possible" (interview #2). "Currently in the tenders, there are points given for using electricity or renewable fuels, even hydrogen is now listed as an option. So, one might get even better money with that. It is sometimes controversial when it is required to use electricity for production, but still hydraulic oil is running in the machine - just the power for the process is produced without fuel. However, then there is a diesel generator close by. Personal protection, falling protection, belt guards, spillage trays, and precipitation pools are required pretty much everywhere already. And the bigger the customer is, the tighter are the requirements" (interview #4).

4.3 Changes in the regulation and requirements

After addressing the current situation, the interviewees gave their insight into how these matters have changed from the past. All the interviewees stated that the changes during the last approximately five years have been more rapid than before and have brought a significantly larger scope for the requirements. Sustainability criteria have been introduced, considering environmentally friendlier fuels, and controlling dust and noise emissions, for example. "There were no biofuels ten years ago or other requirements, but within the last

year all the demands have tightened” (interview #1). “Some customers started asking for the possibility to use cleaner fuel about five to six years ago. Since then, it has gotten more and more common, and the expectations are tighter. Many customers have woken up regarding safety issues, and even since last autumn, the change has been rapid. For example, the clothing requirements have become more specific, and different lifting operations need to have a plan made” (interview #2). “After Talvivaara failed, the regulation became very tight. Even with the smallest sites, it is referred to Talvivaara and the accidents there” (interview #3). “Regulations and especially the conditions for permits have gotten stricter gradually within the past years” (interview #5). “More detailed information is required nowadays. A few years ago, it was enough to just state that one will control dust and noise, but now it is necessary to give more detailed information about the actions to prevent harm. Also, there seems to be interest in the plans for placing the crushers and stockpiles, whether they are down in the pit or on higher ground” (interview #6). “The improvement has been significant in the past five years. Especially, dust and noise are under a closer loop. Closed pits need to be landscaped properly” (interview #7). “The summer breaks start nowadays earlier and last longer. Emission control requirements have gotten tighter, and biodiesel is also sometimes obligatory. And for example, nowadays a report is needed where all waste is taken to” (interview #8). “The demands for protection for spillages, control of emissions, and where one can place the equipment have got stricter” (interview #9).

People can make a complaint about different permit applications. For example, in the Land Extraction Act, people who are directly involved in the matter, live in the municipality, registered associations promoting environmental protection, the Center for Economic Development, Transport and the Environment, and other officials regulating general interest, have the possibility to make a complaint on the permit application (Land Extraction Act 555/1981 § 20 a). The interviewees have noted that the permit applications currently take several years. “The people have a lot of power. If one lives even outside the impact area of the site, they have the possibility to make things difficult” (interview #3). “Quite many of the permits need to go even through the Supreme Administrative Court, especially if there are a lot of complaints” (interview #5). “The time for renewing an environmental permit has doubled, and usually it needs a whole bunch of extra reports” (interview #7). “When applying for a new permit, the process can take ten years. First with all the officials and then there is the possibility to make complaints, which adds three years immediately. In some places even the local politicians have their influence in the process, usually making things even more difficult” (interview #9).

4.4 Regulation trends

Though there cannot be any certain knowledge yet of how the government, municipalities, or clients will act in the future, the interviewees had the possibility to predict the possible outcomes according to their expertise, gut feelings, and possible rumours. The general insight of the interviewees was that the regulation will become tighter in the future, but they are hoping for a pause for a while for any new requirements. "I think it is getting tighter, which is a good thing, as the planet needs to be protected" (interview #3). "I don't think anything drastic will occur in the near future, but maybe in ten years things can be different. It seems to get stricter with the requirements" (interview #4). "I do not know what will come, but hopefully it will not get more difficult. But it might be that there will be more samples from the surroundings for control. Quartz dust was a rising issue a couple of years ago, but now it has been forgotten" (interview #6). "It might be politics, but it seems that the officials try to make things a bit harder. Prolonging the processing times, tightening regulations, etc. But the regulations are not too tight, yet. We just must manage to cope with them. I wish the officials would co-operate with us entrepreneurs to have a better idea about the practicalities in the operations" (interview #7). "The regulation will be tighter in the future. More demands for permits and more requirements from big customers. Although, as the world is so uncertain now, it might slow these changes down a bit" (interview #9).

Environmental sustainability is expected to gain ground with stricter regulation and with cost guidance. Reporting is also expected to get more detailed. "Carbon footprint could be required to be calculated, but it needs to have a universal and official procedure to do it with" (interview #1). "Using older, not-so-sustainable equipment, will be more and more expensive due to European and Finnish regulations. It forces to renew the equipment to cleaner ones." (interview #2). "To get an environmental permit, one needs to operate with electricity, for example - even though the separate diesel generator produces the electricity" (interview #4). "The trend seems to go towards electric equipment, though, with mobile machines, there are difficulties moving with the cables if they are connected to the public power grid. In public contracts, you need quality and environmental certificates to be able to even bid" (interview #5). "Most likely emissions are followed more carefully and changing different substances in to more environmentally friendly" (interview #8).

4.5 Issues with regulations

In this subject, the interviewees shared their experiences of possible hardships trying to meet the set criteria for permits or being able to bid for certain contracts with higher sustainability requirements. Though the regulation has tightened during the past few years, almost all the interviewees have not had problems meeting the preconditions. Their equipment has been up to the standards or required only slight adjustments – or they have been selective with the tenders they bid in. “We have not had any problems meeting the requirements yet or have not had to renew our equipment” (interview #1). “We have been fine with all the demands so far. We have not offered for contracts which have had stricter requirements than we can match” (interview #4). “We have not had problems with regulations, as we have decided to be proactive and keep our equipment and processes a bit above the required limit. Sometimes it is difficult if, for example, it is required to use the public power grid, but there is no suitable transformer available, as the equipment needs quite a large amount of power. And it costs over 100 000 euros, so usually the customer is happy with another option - using the diesel generator, in our case” (interview #5). “Some manufacturers suggest the use of separate ladders with the equipment, and that does not meet the safety standards. In those cases, we have made some changes to the required spots” (interview #8).

The difficulties some have encountered, have mostly been internal and related to the personnel. In some places, the set restrictions for activity on the site have brought some hardship, and some of the regulations have caused the need to change some parts of the equipment. “Our biggest challenge has been the resistance for change in the personnel, especially older ones” (interview #2). “Generally, we manage with the regulations, but sometimes the set limits for working times are unreasonable. One pit has nothing near it, and it has restrictions for even picking up materials, which causes no dusting or disturbance for anyone. It is likely a general rule, which is applied everywhere in the district, regardless of the actual surroundings” (interview #7). “Some of the personnel have troubles living up to the requirements, for example using a helmet” (interview #8). “The emission limits have made big generators obsolete. They cannot reach the required limits, so now we must use two smaller ones. Two units means two times more service, possible more malfunctions, and so on” (interview #9).

One interviewee feels the equipment manufacturers are late with their offerings. “For some contracts, we have not been able to bid, as we could not meet the requirements for certain emission levels. I think the equipment manufacturers are also three to five years late, as they are now bringing new equipment and engines that are not working in the crushing

environment, with the dust and filth, and sub-zero temperatures. Electric options should have been available earlier, so those could be already in use now, but instead they have been with hydraulics and still are” (interview #3).

Though the prerequisites are considered quite strict currently, one interviewee emphasizes that there should be a financial benefit for those, who could operate with a higher level of sustainability. “We have been fine with all the regulations. Actually, I am even a bit disappointed with the tenders from cities and municipalities around here, as they look only at the price. And the requirements are lower than in a lot of other places, as the operators’ machines are not quite up to the latest standards. That means the price would be higher, as there would be only a few companies able to bid” (interview #6).

4.6 Issues with safety and environmental features in equipment

Crushing and screening equipment, especially mobile units, have a lot of different features for safety and environment. For safety, there are service walkways, ladders, service platforms, different types of protection so one does not get themselves stuck or hurt, and emergency stop wires and buttons, for example. The environmental features are mostly related to the engine, reducing the emissions, or the structure of the machine itself reducing the noise from the crushing process, and some optional features, like high-pressure water sprinklers suppressing the dust from the material both in the crushing process and when the material falls from the conveyors. The interviewee’s companies’ equipment was variant. Some had older machines, which had engines without any emission controlling features or only exhaust gas recirculation, but no diesel particle filter or selective catalytic reduction with diesel exhaust fluid, containing urea, which was often mentioned by the interviewees, and all but two had experienced problems with them. “90 percent of problems are related to the urea and emission equipment. That is why they are usually being removed” (interview #1). “The emission devices in the engines are a pain, whether it is the regeneration or urea” (interview #2). “Biggest problems are with urea and regeneration appliances, and if not in the device itself, but the wires connected, etc. That equipment is not designed for a crusher, to withstand the vibration” (interview #3). “Our crushers do not have any emission cleaning devices, so we have been okay with them, but other machines do and those get problems with the urea and regeneration devices” (interview #4). “We have had some problems with the regeneration devices in the engines and also the urea has caused problems, with the sensors and wires” (interview #5). “The urea equipment causes problems constantly and needs to be changed every couple of years. They would need such a clean environment to

function properly, but it is not possible in a crushing station” (interview #8). New models always bring new problems, for example with the emission devices. Once the old ones get fixed, a new model is introduced and brings along new problems. Some issues could be sorted out by using better components” (interview #9).

Issues with safety features were related to both electricity and mechanical problems. It is not always a malfunction in the machine, but possibly something that could be designed better to suit the process. With electricity problems, some of the companies are reliant on external assistance, which causes longer pauses in production, whereas a lot of the mechanical issues can be sorted out by the companies’ own employees at the site. “Sometimes safety features cause problems with production, for example, material building up on finger safety guards (figure 15), or electric problems with emergency stop wires and buttons” (interview #1). “Emergency stops, and other safety device problems, usually electric ones, are most common. Especially in the wintertime, finger safety guards cause problems, and sometimes they are lowered down because of that” (interview #2). “Extreme aspirations for safety make the equipment impossible to use. So much electricity, and emergency stop systems, that are very vulnerable to failures. Also, the demand for dust suppression leads to heavy use of water, which then builds up to the finger safeguards” (interview #3). “Safety devices, the components, could be better. As they are not in regular use, they tend to cause problems when they get into action” (interview #4). “Safety features have worked well mostly, some electric fault once, which was hard to detect, but otherwise they have been working fine” (interview #5). “Emergency stops are very good and absolutely necessary, but very sensitive for malfunctions. The changing environment builds up moisture in them and causes troubles in the electricity” (interview #8). “Sometimes the safety features are exaggerated, or not just functional in the daily work. These need to be dealt with the manufacturer to get changes in them” (interview #9).

Figure 15. The finger safety guards (Metso Corporation, n.d.-n).



Finger safety guards are metal plates in front of the idling rollers, preventing fingers and hands from getting sucked in between the moving roller and conveyor belt (figure 14). They can be found beneath all conveyors.

Two of the interviewees said they either had not had any significant problems with the environmental or safety features in the machines, or they had been able to easily resolve them. “We have still Tier III -diesel engines, so we have avoided the problems with the emission control devices. We have not had any bigger issues with the safety devices either” (interview #6). “We have managed well with our equipment” (interview #7).

4.7 Changes made to equipment properties

To make profit from the contracts, the operators need to have their production up and running as much as possible and have preferably only planned stoppages – but quite often there emerges unexpected problems with the machines. Practises for upkeeping the production and reworking the equipment unveiled differences in the interviewees’ companies. Some had a very clear policy that no permanent modifications were to be done to the machines, either because of external service contracts, fear of consequences, or just having an internal rule of keeping the equipment original. “Some electric problems, for example with emergency stops, that could not be fixed immediately or waited for the service to come, so they needed to be bypassed for the time being. Otherwise, we try to keep the equipment in its original state” (interview #4). “We do not make any changes, as we usually have a service contract for the equipment” (interview #6). “It will now be criminalized to bypass or remove the urea equipment, so if someone does so, they will put themselves hanging by a thread.

So, we have not made any changes to our equipment” (interview #7). “We have not modified anything permanently. In some cases, we have had to make a bypass for emission devices, but those were restored back to normal once service people have come to fix the problem” (interview #9).

Finger safety guards prevent fingers from getting caught between an idling roller and a conveyor belt. Some interviewees mentioned that the material stuck on the belt starts to build up on these finger safety guards and eventually wears out the roller quickly. The cleaning of these guards was felt inconvenient, so some have removed a few of them and some most of them. “Most of the finger safeguards have been removed” (interview #1). “Due to the material build-ups, we have had to remove some of the finger safety guards” (interview #3). “We have removed a couple of finger safety guards from the conveyor underneath the primary crusher, as they pile up material, especially in wintertime, and no one has any reason to go there when the process is running” (interview #5).” We have modified the finger safeguards, so they would work better” (interview #8).

Some modifications to the mobile units’ structures had been done, as well. Those were related to improving safety or changing the structure of service walkways on the unit. Mobile units usually have service platforms next to the power unit, next to the crusher, and going around the screening box (figure 16). “In one track, due to the transportation width limits, the walkways were so narrow, one could not fit to go through, so we had to remove the railings” (interview #3). “We had to add some rubber curtains to prevent rocks from bouncing down from the screen” (interview #5). Some units have so wide service walkways on the sides of the screen box, that they do not fit in all places, so there we have done some modifications” (interview #8).

Figure 16. Service platforms of a mobile unit (Metso Corporation, n.d.-n).



The engine-related problems, usually with the diesel particle filter or selective catalytic reduction, have led to bypasses and complete removals of these devices. “Mainly all exhaust devices are in use, but sometimes a bypass is needed when the machine has lower usage” (interview #1). “We have removed some emission devices, due to continuous malfunctions. Also, a fault reading device was purchased to get along with the problems, as many times service was available for the following day, which means the production for that day is pretty much lost already” (interview #2). “We have had to also remove some of the emission cleaning devices from engines, as they just did not work well enough. The constant stoppages cause the emptying of the crusher chambers, which is not safe either. And if some sensors etc. are not in the local warehouse, there will be a day or two of missed production” (interview #3).

4.8 Accidents with equipment

In this topic, the interviewees told how their safety measures had succeeded at their sites and if there had been any accidents related to the operation or maintenance of crushing or screening units. For most of them, the ways of working and the safety of the machines had prevented any accidents from happening. “Luckily no accidents have occurred” (interview

#1). “No accidents with our equipment” (interview #2). “We have not had any bigger accidents, maybe someone slipped a foot in winter, but nothing else” (interview #5). “No accidents, and hopefully it will continue like that” (interview #6). “We have had luck and no accidents so far” (interview #7). “No, we insist on working in safe manners, so accidents would not happen” (interview #9).

Three of the interviewees told about accidents, which had happened in daily activities or during maintenance work. These incidents did not lead to any serious consequences, but they made some changes to the procedures or equipment. “Some small accidents have happened. For example, changing the v-belts of a primary crusher, which needs to be done from a ladder and the ground is not level, and in any case, there is the risk of falling down from the ladder” (interview #3). “I do not recall any bigger accidents, maybe fingers getting caught between some parts, but nothing else. Once I got my arm pulled between a drum and a conveyor belt, when I was trying to get the dirt out of there with a dustpan, and the dustpan got sucked in and my glove did not strip off, so my arm went in as well. Luckily it was a smaller conveyor with less power and workers were right there to help, so nothing serious happened” (interview #4). “The latest accident happened when the workers were changing screening media and one person fell down from the conveyor when a stuck mesh suddenly came loose. Luckily nothing serious happened. We then added rails there, so it would not happen again. Occasionally someone gets their fingers in a tight place when changing a roller, for example. Usually, it is because they are hurrying and not being careful” (interview #8).

4.9 Benefits for sustainability forerunners

Companies and entrepreneurs aim to have a profitable business, and the Limited Liability Companies Act states that it is the purpose of the company to make profit for the shareholders, unless there is an exception in the Article of Association (Limited Liability Companies Act 624/2006 § 5). The interviewees were in different phases regarding the sustainability of their operations, and they discussed their experiences and opinions, whether there is a financial benefit of being a sustainability forerunner or striving to become one. Many of the interviewees said the business is still very cost-driven, and even if there would be the impression of sustainability being an influential factor, it still comes down to the cheapest price in the end. “It is hard to see the benefits of doing more than what is required. In tenders, you might get some comments about sustainability, but in reality, it is about the price. Customers are not that interested in carbon neutrality, for example. I have not seen a

possibility to get a better price for products, if they are produced more sustainably” (interview #3). “I do not see any actual benefit, financially or for image, for doing more than necessary. It is unfortunate, but at the moment it seems to be like that” (interview #6). “It might be, that in the future there will be benefits from that, but now it means only bigger costs. Though, in business, one should have a bit longer view into the future” (interview #7). “In tenders, there are points given for being sustainable, but the significance of price is still up to 70 percent, so there is not much left for the green values to overturn the race. So, currently, there is no sense being a forerunner, as the cost level is so high, and it does not increase the revenues” (interview #8).

Some of the interviewees saw the possibility of creating a better image of the company, and differences between private and public clients’ values. “Though you do not get any extra points for exceeding the sustainability requirements in tenders, you give a better image of yourself. If you fall behind with the development, it is hard to catch up” (interview #1). “For those customers who appreciate it. But most of the private site owners are interested in the cost only. Public litigants have different values and that shows in the tenders” (interview #4). “We have been a bit ahead all the time regarding environmental aspects, but I do not think there is a direct financial benefit for it. Of course, it can open possibilities to bid for more contracts, but it will not improve your profitability” (interview #5).

Two interviewees gave examples of the direct benefit of acting more sustainable than the lowest requirements would be. Not only the financial and reputational benefits were highlighted, but also the possibility to influence how the processes run with authorities and what the requirements should be. “Being more sustainable might bring you longer contracts, five years instead of three, for example. If it does not become the restricting element for production, I do not see any harm from it” (interview #2). “Better reputation is one benefit. When highlighting sustainability, both environmental and safety, others regard them as a trustworthy partner. It also opens the possibility to educate the officials, and politicians, on how things are actually done in the aggregate production and what are the realities there. Though it brings along higher costs, all endeavours for progress bring costs. But it is a decision to be a company, which strives to improve things and bring something new to the whole industry, even with the slight hit to profits” (interview #9).

4.10 Discussion

The Finnish aggregate production industry is very little studied, and the voice of the operators is somewhat unheard. With the growing sense of urgency with global warming, and

the regulation deriving from it, the target of the thesis was to find out how these changes affect the ground level of operations; the daily activities, uptime of stations, and the profitability of the companies.

Table 2. Simplified stances for different topics.

Topics	Company								
	1	2	3	4	5	6	7	8	9
Stance for sustainability	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
Current regulation	Difficult	Neutral	Difficult	Neutral	Neutral	Neutral	Neutral	Difficult	Difficult
Changes in regulation	Stricter	Stricter	Stricter	Stricter	Stricter	Stricter	Stricter	Stricter	Stricter
Trend of regulation	Stricter	Stricter	Stricter	Stricter	Stricter	Neutral	Stricter	Stricter	Stricter
Issues with regulation	No	Yes	No	No	No	No	Yes	Yes	Yes
Issues with equipment	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Changes in equipment	Yes	Yes	Yes	Temporary	Yes	No	No	Yes	Temporary
Accidents occurred	No	No	Yes	Yes	No	No	No	Yes	No
Financial benefits	No	Yes	No	Some	No	No	No	No	Yes

Table 2 presents a simplified summary of the interview results. The traffic light colour coding helps to tell the differences in insights easily, though in some cases the opinion was not that strict. The green colour is a mark for a positive, yellow indicates neutral, and red is a negative. Regarding the regulation, colour marking is a very subjective decision and should not be considered as the author's opinion about the matter. Many of the interviewees felt the strict regulation was a somewhat negative factor, therefore it has a red colour. The same logic applies to the expectation of regulatory changes. For the changes made to equipment, the red colour for making the changes indicates the lack of quality, design, or maintenance of the equipment, so the operator has been forced to make the changes due to malfunctions. Temporary changes have been marked as yellow, as they were restored to their original state, when the problem had been solved. It can be seen, that in some cases the column shows a lot of red, meaning they have experienced the regulations difficult to meet, have had troubles with their equipment and made changes to the safety and/or ecological features, have had accidents with their equipment, and do not see any financial benefits to achieved from being a sustainability forerunner.

Overall attitude towards sustainability was very positive among the nine interviewees. They share the worry about the environment and the future of the planet and understand the reasons for the tightening regulations. They are a bit disappointed in the authorities' long-lasting processes with different permits and the extensive possibilities to make complaints about applications. Also, the territorial differences in policies and interpretation of legislation are considered to be unfair. Most of the interviewees expect the regulation to become even tighter in the future.

New technology in the crushing and screening equipment provides the possibility to meet the requirements in the permit applications and increase the sustainability of the operation. The latest models are more fuel efficient, have the possibility to use external electricity to power up the machine, generate less greenhouse gases, and reduce noise better than older equipment (Metso Corporation, 2020). Newer machines are also safer for the workers and accidents happen very seldom when operating or maintaining the equipment. On the other hand, this new technology means more electricity, which is prone to malfunction in the challenging environment of tremors, dust, rain, snow, and sub-zero temperatures. If the machines run with the power of a diesel engine, the devices cleaning the exhaust gases are causing problems quite often, and for the same reasons as the electricity-related troubles. Some of the interviewees said, that their workers have had to make at least temporary bypasses e.g., for emergency wires or stops and the urea equipment in the engines, in order to keep the production running while waiting for the service personnel or spare parts to arrive.

Only two of the interviewees reported financial benefits from investing in the sustainability of the operations. Despite the higher costs, the reputation of a sustainable partner is related to longer contracts and more trustworthy partnerships. Others pointed out, as well, that some tenders have certain sustainability requirements, which automatically limits the possibility of bidding for those contracts if one's equipment is not up to the standards. For the most, the endeavour for sustainability means just more costs. Newer technology and equipment are more expensive, environmentally friendlier diesel is more expensive (Klemola, 2023), and in most extraction sites the electric grid is not available for use. In the tenders, the sustainability factors do not usually increase the price of the products and the buyers emphasize the cost over sustainability, which does not encourage the operators to invest more into their equipment and operative sustainability. The interviews highlighted the difference between private site owners and public actors, where the private owners do not have so many requirements besides legislation, whereas the cities, municipalities, and big enterprises have their own sustainability targets and agendas, which do show in their tenders, but according to the interviewees of this study, the cost is still the most significant factor.

5 Conclusion, limitations, and future research

5.1 Conclusion

The findings from this study point out, that within this research group, sustainability is seen as an important aspect of operations. It brings along complexity when transacting with the authorities, and the interpretations of the same laws and regulations vary in different parts of Finland. Applying for new environmental and extraction permits was stated to be a long process, taking up to a decade, as the complaints prolong the case. The interviewees expected that the regulation would get even stricter in the future, though it was experienced quite strict already.

Complexity was not associated with the permit applications only, but also with the equipment with new, environmentally friendlier, and safer technology. The improvements to these aspects often come with an increase in components prone to both electric and mechanic failures. These faults cause stoppages of production and often require external help to be solved. Continuous production is a key factor for profitable operation, so these failures may lead to temporary solutions, or in some cases permanent changes to the equipment, to ensure a steady operation. Though some of the changes were made to safety features, the reported accidents with the equipment were not directly related to those changes, but do raise a question, of whether there should have been a preventative measure applied.

The studies introduced in the theoretical framework indicated a positive connection between sustainability investments and financial performance. The reputation and image of the companies were reported to be better and so forth attracting investments and strengthening the relationships with stakeholders. Similar insights arose from this study, as several interviewees mentioned the better image of the company because of sustainable operation. Though they did not mention higher prices for contracts, the length of contracts could be longer, and the possibility to bid for contracts, where the requirements are higher. There was no doubt left, that the costs are higher when aiming for more sustainable operation. On the other hand, as one interviewee pointed out, all investments cost money and if the company wants to be seen as a forerunner and willing to renew the industry, those investments need to be done.

The main research question of this study was to find out the effect of sustainability initiatives on the producing company's financial performance, and what kind of an impact the current

regulations and technologies have on it. From the results of this study, it can be said that sustainability actions do not bring a direct increase in the cash flow of the company. The costs are higher for the producer, but often the pay from the clients is not. Being sustainable can bring more opportunities for contracts and lengthen them, though, and improve the company's image both to the public and the company's stakeholders. The regulations can bring hardships, especially when varying between different areas, but otherwise, it is also seen as a good baseline to preserve the condition of the environment. New technology improves the safety of operators and protects the environment but causes disturbing production stoppages due to the contingency of the functionality.

If sustainability would be a priority in the industry, those attributes should be emphasized in the tenders, weighing more than the unit price for products. At least the costs of using cleaner options should be compensated to make it sensible for the operators to use such alternatives. As there are also desires to increase the use of electricity for powering the equipment, the power grid should be extended to cover the quarry sites, so there would not be a need to use diesel engines in the machines or an external diesel generator.

5.2 Limitations of the study

The semi-structured interview can also be questioned. Diefenbach (2009) presents many critical views about the whole study process. He points out that the researcher's own stance and perspectives might determine the research question and methodological approach, and that the research question would change throughout the process. The rigorousness of this type of study is questionable, as though there are several methods for investigating the research question, there are no specific ones, so the outcome between different researchers could vary. As the objects of the studies are human beings, with changing views about issues, similar studies might bring different results, and therefore the reliability is untrustworthy. Diefenbach also states that investigative case studies do not usually have a certain theory to back up the study. The selection of interviewees is also criticized for being disorganized and subjective, favouring the already established connection instead of emphasizing the purpose of the sample. In addition, the interview situation might distort the data, due to the interviewees' unconscious bias or the incapability to answer some topic, or the unwillingness to answer truthfully for some reason. The internal validity of data comprises the quality, quantity, and time frame of collection. Regarding the quality of the collected data, the triangulation of the is often insufficient, and for the quantity, there is no known limit when there are enough interviews conducted to have enough data collected. Furthermore, the

interviews are made at that specific moment and the longitudinal studies are missing. The researcher also affects the internal validity of data, as the selection of included data in the report lies usually solely on the researcher. This points out the subjectivity in the study, as there is no algorithm, for example, to pick which parts of the discussions are to be included and what is their importance. The data could be coded and analysed by two researchers independently and then compared to improve the quality, but still the choices made would be subjective. The subjectivity continues in the writing of the report, as the author makes the interpretations of ambiguous discussions. All of this leads to the conclusion, that the results of these studies can neither be generalized nor produce any theories. (Diefenbach, 2009)

The size of the research group was nine cases, limited only to Finland, and the companies were customers of the commissioning party, Metso Corporation. Expanding the research group in quantity, geographically, and the suppliers of equipment could bring more information about the subject. The interviewees' insights were expressed at that specific time, and in the future, they could be different.

5.3 Future research

Due to the sample size and limitation to Finland, similar studies could be made, for example, in other Nordic countries or in the European Union countries, which have similar targets for sustainability as Finland. As this study was qualitative research, a different approach with a quantitative study could be an option to further explore this subject. Future research could follow up on the progress of these sustainability initiatives in Finnish aggregate production, whether there will be a bigger change at some point, leading to a quicker renewal of equipment and processes, changes in legislation and regulation, and if there will be more financial benefits for those, who act swifter to renew their operation closer to carbon neutrality.

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Appendix 1. Topics of the interviews

- What insight do you have about sustainability in general, regarding the ecological, safety and financial aspects?
- What are your current opinions about the legislation and regulation concerning the aggregates industry? What experiences have you had regarding them?
- Have the regulation and legislation changed and within what timeframe?
- Has your company faced any issues meeting the regulation?
- What is your vision of the future regarding sustainability in the aggregates business?
- What is your stance regarding the environmental and safety features in the crushing and screening equipment? Have you experienced problems with them?
- Have you modified the environmental and/or safety features in the equipment?
- Have you faced any health and safety issues when operating or maintaining the equipment?
- Do you see any benefits for being a sustainability forerunner, in a short and longer term?

Appendix 2. Data management plan

The collected data from this thesis includes audio files from the conducted interviews. The interviews were recorded with the author's mobile phone and stored in the author's personal cloud storage, iCloud, and the backup files in the author's personal laptop computer. Both devices have biometric scan for entering, or a password required. The cloud storage also needs a password for entering. None of the audio files had any personal or confidential information included, only the date of the recording and the device added a location to the file name, which were not accurate in all cases. No other person had access to the interview data. The data is to be remained in the author's possession, will not be used for any further use, and will be destroyed after one year from the approval of this thesis.

The author of this thesis is the owner this work along with the commissioner, Metso Corporation. If the results are to be used somewhere, the names of the author and supervisor are to be declared according to the research integrity.